Fermilab

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DCA311 End Loads from End Bell Welding

This note presents the end force data from the bullet gauges on DCA311 taken during the welding of the end bell to the end plate and during the loosening of the bullets after the welding was complete. The welding required 31 passes -- 1 root fusion pass and 31 filler passes. The bullets were initially loaded to 100 lbs each[1] and they were read out after each weld pass after the region had cooled to the specified inter-pass temperature[2]. This process spanned a period of about 50 hours.

The data are tabulated in Table I and plotted in Figure 1 (end force versus weld pass) and Figure 2 (end force versus time). When the weld crew broke either for the night or for lunch, measurements were taken both at the time the temperature reached the specified value and before work resumed. The latter reading is always higher because the structure has cooled more. These appear as steps at weld passes 8 (over night between 10/9 and 10/10), 16 (lunch on 10/10) 26 (over night between 10/10 and 10/11) and 31 (over night between 10/11 and 10/12 after the job was complete). The "connect-the-dots" lines in Figures 1 and 2 are broken at the points corresponding to the breaks in the welding operation. After weld pass 27 three sets of readings were taken and the increase with cooling is evident.

The end force increased only very slowly for the first 17 passes, then increased very rapidly for the next several passes, and then slowed down to a more moderate rate after pass 23. There is a significant decrease between passes 27 and 28 which is not understood. The final end force is, on the average, a few hundred pounds higher than on DCA310 despite changes[1] in the procedures.

The cause of the rapid increase, corresponding to about half the final load, between passes 17 and 23 is not known. Several hypotheses have been put foward. John Carson suggests that this corresponds roughly to the point at which as much filler had been added to the outboard (end bell) weld as was previously added to the in board (shell) weld. At this point the end plate is somewhat unstable and "pops" like a Belleville washer from bulging outwards to to bulging inwards. It has also been suggested that the change in sloped might be caused by a failure of some of the welders to follow the proper schedule. For example, there were changes of welders between, at least, passes 17 and 18 and between passes 19 and 20, corresponding to the perios of steepest slope. (Also the period of most rapid increase is on the day that Bill Higinbotham was at BNL and could not keep a close eye on the process.) My personal view is that it is undesirable that the end loads should be this sensitive to the details of how the ends are welded.

After the welding was complete the bullets were loosened until the end force was reduced to approximately 1000 lbs/bullet. The bullets were loosened one at a time in increments of 1/32 and then 1/16 of a turn and the force on all the bullets was measured after each incremental turn of one bullet. These data are shown in Table II. The first block of columns indicates which bullet was loosened on each step. The second block shows the net displacement of each bullet in inches using the 16 threads per inch thread pitch. Next are the end forces and then the averages of the displacement and the end force. The same data are displayed in Figure 3 (force versus measurement number) and Figure 4 (force versus displacement). In Figure 3 the solid symbols show the forces and the open circles give the incremental turns of each bullet, indicating which bullet was turned for each measurement. The average force versus displacment is compared in Figure 5 with the previous measurements[1]. The data are normalized to the earlier measurements at 3000 lbs. The slope on unloading is much less steep than on loading. It is not understood why this is.

To reduce the load to 1000 lbs required loosening the bullets by between 1/2 (bullet 1) and 25/32 (bullet 2) turn. To limit the load at the uninstrumented lead end of DCA311 the set screws will first be loaded to a torque of 10 in-lb, corresponding the the initial 100 lbs load at the return end, and then backed out 1/2 turn, the minimum required at the return end. It is currently planned to follow the identical procedure at the return end of DCA312, which will allow a check of its efficacy.

REFERENCES

[1] J. Strait, DCA311 and DCA312 Return End Coil Spring Rates, TS-SSC 91-194, 10/7/91.

[2] W.A. Higinbotham, End Cap/Extension Assembly Installation, 0102-ES-292405 Rev. None, 7/24/91.

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Table I

Welding the End Bell

Date	Time	Date	Time	Weld pass	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Total Force
10/9/91	12:45	10/9/91	12:45	1	180	166	205	200	751
10/9/91	16:00	10/9/91	16:00	2	190	192	229	205	816
10/9/91	16:40	10/9/91	16:40	3	188	187	242	218	835
10/9/91	17:10	10/9/91	17:10	4	194	191	262	222	869
10/9/91	17:30	10/9/91	17:30	5	193	201	282	219	895
10/9/91	17:55	10/9/91	17:55	6	212	229	310	220	971
10/9/91	18:10	10/9/91	18:10	7	217	244	321	225	1007
10/9/91	18:35	10/9/91	18:35	8	225	263	342	237	1067
10/10/91	7:15	10/10/91	7:15	8	350	494	460	456	1760
10/10/91	8:10	10/10/91	8:10	9	393	567	517	523	2000
10/10/91	8:35	10/10/91	8:35	10	397	566	528	535	2026
10/10/91	8:55	10/10/91	8:55	11	422	586	581	617	2206
10/10/91	9:15	10/10/91	9:15	12	418	572	569	611	2170
10/10/91	9:35	10/10/91	9:35	13	440	610	611	664	2325
10/10/91	10:22	10/10/91	10:22	14	487	701	718	810	2716
10/10/91	10:55	10/10/91	10:55	15	531	782	809	925	3047
10/10/91	11:18	10/10/91	11:18	16	590	884	929	1056	3459
10/10/91	12:35	10/10/91	12:35	16	731	1041	1114	1255	4141
10/10/91	13:15	10/10/91	13:15	17	772	1072	1124	1278	4246
10/10/91	14:10	10/10/91	14:10	18	1008	1289	1450	1604	5351
10/10/91	15:03	10/10/91	15:03	19	1431	1730	1897	2149	7207
10/10/91	16:07	10/10/91	16:07	20	1705	2003	2208	2551	8467
10/10/91	16:40	10/10/91	16:40	21	1857	2137	2357	2776	9127
10/10/91	17:02	10/10/91	17:02	22	1981	2278	2478	2928	9665
10/10/91	17:35	10/10/91	17:35	23	2111	2404	2621	3076	10212
10/10/91	17:50	10/10/91	17:50	24	2071	2349	2573	2965	9958
10/10/91	18:10	10/10/91	18:10	25	2121	2394	2614	3029	10158
10/10/91	18:39	10/10/91	18:39	26	2144	2412	2626	3045	10227
10/11/91	7:06	10/11/91	7:06	26	2574	2915	2987	3516	11992
10/11/91	8:40	10/11/91	8:40	27	2544	2824		3414	
10/11/91	8:50	10/11/91	8:50	27	2586	2890	3010	3441	11927
10/11/91	8:55	10/11/91	8:55	27	2600	2915	3036	3486	12037
10/11/91	9:45	10/11/91	9:45	28	2284	2534	2731	2939	10488
10/11/91	10:38	10/11/91	10:38	29	2332	2574	2793	3011	10710
10/11/91	11:14	10/11/91	11:14	30	2475	2728	2940	3283	11426
10/11/91	12:45	10/11/91	12:45	30	2656	2948	3112	3595	12311
10/11/91	13:35	10/11/91	13:35	31	3005	3189	3426	3934	13554
10/12/91	7:41	10/12/91	7:41	31	3235	3410	3592	4164	14401
10/12/91	8:13	10/12/91	8:13	31	3202	3377	3574	4135	14288

Table II

Loosening the bullets to 1000 lbs each

	Incremental Turns of the Screw				Displacement (inches)				Force (lbs)				<Δz> (in)	<F> (lbs)
Seq. No.	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Bullet 1	Bullet 2	Bullet 3	Bullet 4		Average
1					0.000	0.000	0.000	0.000	3202	3377	3574	4135	0.000	3572
2				0.031	0.000	0.000	0.000	-0.002	3262	3409	3628	3753	0.000	3513
3		0.031			0.000	-0.002	0.000	-0.002	3250	3396	3617	3757	-0.001	3505
4			0.031		0.000	-0.002	-0.002	-0.002	3280	3484	3009	3898	-0.001	3418
5			0.031		0.000	-0.002	-0.004	-0.002	3300	3564	2342	4042	-0.002	3312
6	0.063				-0.004	-0.002	-0.004	-0.002	2163	3753	2387	4252	-0.003	3139
7		0.063			-0.004	-0.006	-0.004	-0.002	2285	3022	2480	4307	-0.004	3024
8				0.063	-0.004	-0.006	-0.004	-0.006	2399	3090		3450	-0.005	2980
9			0.063		-0.004	-0.006	-0.008	-0.006	2397	3126	2313	3524	-0.006	2840
10	0.063				-0.008	-0.006	-0.008	-0.006	1700	3267	2336	3659	-0.007	2741
11				0.063	-0.008	-0.006	-0.008	-0.010	1776	3303	2410	3138	-0.008	2657
12		0.063			-0.008	-0.010	-0.008	-0.010	1790	3167	2428	3154	-0.009	2635
13				0.063	-0.008	-0.010	-0.008	-0.014	1859	3202	2505	2564	-0.010	2533
14		0.063			-0.008	-0.014	-0.008	-0.014	1913	2864	2547	2595	-0.011	2480
15		0.063			-0.008	-0.018	-0.008	-0.014	1975	2510	2587	2623	-0.012	2424
16				0.063	-0.008	-0.018	-0.008	-0.018	2032	2543	2656	2124	-0.013	2339
17			0.063		-0.008	-0.018	-0.012	-0.018	2042	2595	2336	2197	-0.014	2293
18		0.063			-0.008	-0.021	-0.012	-0.018	2091	2276	2383	2221	-0.015	2243
19		0.063			-0.008	-0.025	-0.012	-0.018	2141	1984	2421	2239	-0.016	2196
20			0.063		-0.008	-0.025	-0.016	-0.018	2151	2048	2057	2314	-0.017	2143
21				0.063	-0.008	-0.025	-0.016	-0.021	2205	2079	2135	1852	-0.018	2068
22	0.063				-0.012	-0.025	-0.016	-0.021	1830	2148	2145	1922	-0.019	2011
23			0.063		-0.012	-0.025	-0.020	-0.021	1846	2211	1790	2013	-0.020	1965
24		0.063			-0.012	-0.029	-0.020	-0.021	1913	1840	1764	2034	-0.021	1888
25				0.063	-0.012	-0.029	-0.020	-0.025	1987	1875	1851	1470	-0.021	1796
26	0.063				-0.016	-0.029	-0.020	-0.025	1838	1907	1857	1505	-0.022	1777
27			0.063		-0.016	-0.029	-0.023	-0.025	1849	1958	1533	1569	-0.023	1727
28		0.063			-0.016	-0.033	-0.023	-0.025	1912	1615	1584	1586	-0.024	1674
29	0.063				-0.020	-0.033	-0.023	-0.025	1690	1668	1592	1619	-0.025	1642
30				0.063	-0.020	-0.033	-0.023	-0.029	1744	1683	1654	1273	-0.026	1589
31		0.063			-0.020	-0.037	-0.023	-0.029	1806	1363	1696	1290	-0.027	1539
32	0.063				-0.023	-0.037	-0.023	-0.029	1495	1437	1706	1337	-0.028	1494
33			0.063		-0.023	-0.037	-0.027	-0.029	1508	1492	1337	1415	-0.029	1438
34	0.063				-0.027	-0.037	-0.027	-0.029	1203	1564	1354	1460	-0.030	1395
35			0.063		-0.027	-0.037	-0.031	-0.029	1219	1613	1007	1583	-0.031	1356
36		0.063			-0.027	-0.041	-0.031	-0.029	1261	1367	1046	1548	-0.032	1306
37				0.063	-0.027	-0.041	-0.031	-0.033	1312	1387	1110	1203	-0.033	1253
38		0.063			-0.027	-0.045	-0.031	-0.033	1348	1205	1135	1216	-0.034	1226
39	0.063				-0.031	-0.045	-0.031	-0.033	1020	1281	1148	1266	-0.035	1179
40		0.063			-0.031	-0.049	-0.031	-0.033	1067	1065	1172	1275	-0.036	1145
41				0.063	-0.031	-0.049	-0.031	-0.037	1103	1087	1208	1092	-0.037	1123
42			0.063		-0.031	-0.049	-0.035	-0.037	1102	1103	1044	1132	-0.038	1095

DCA311 Return End Bell Welding

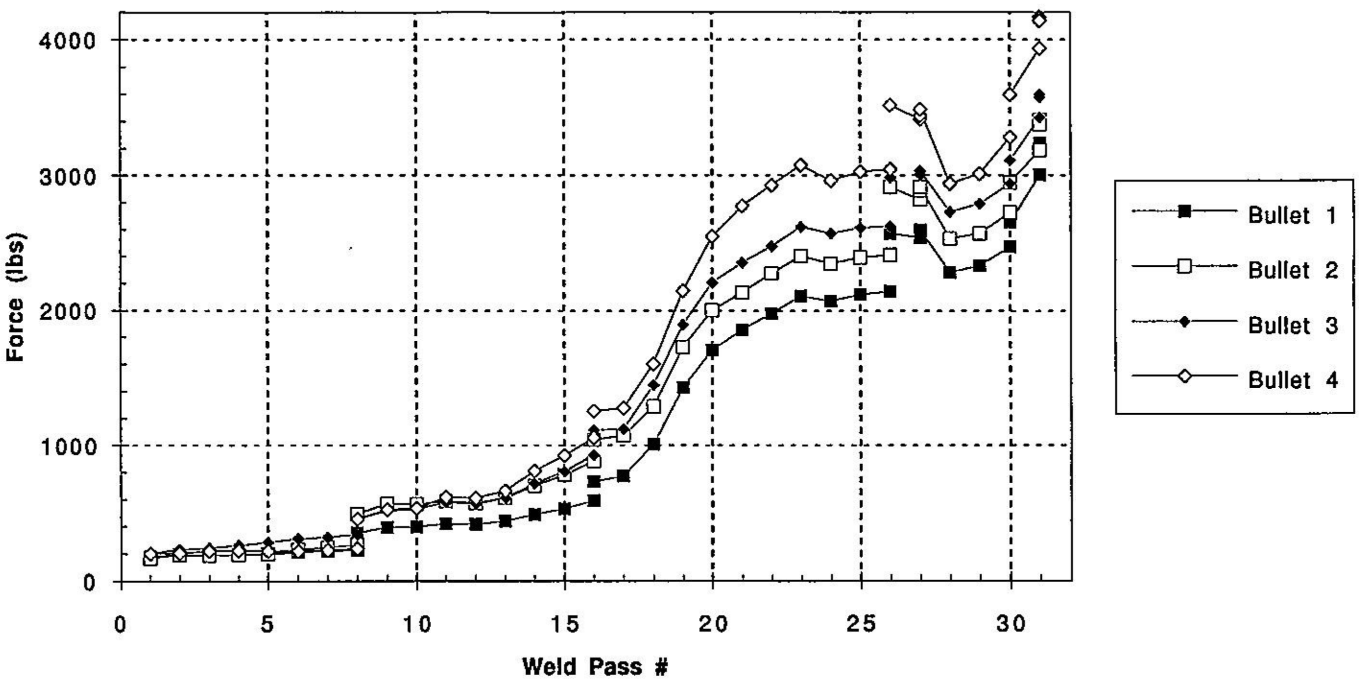


Figure 1

DCA311 Return End Bell Welding

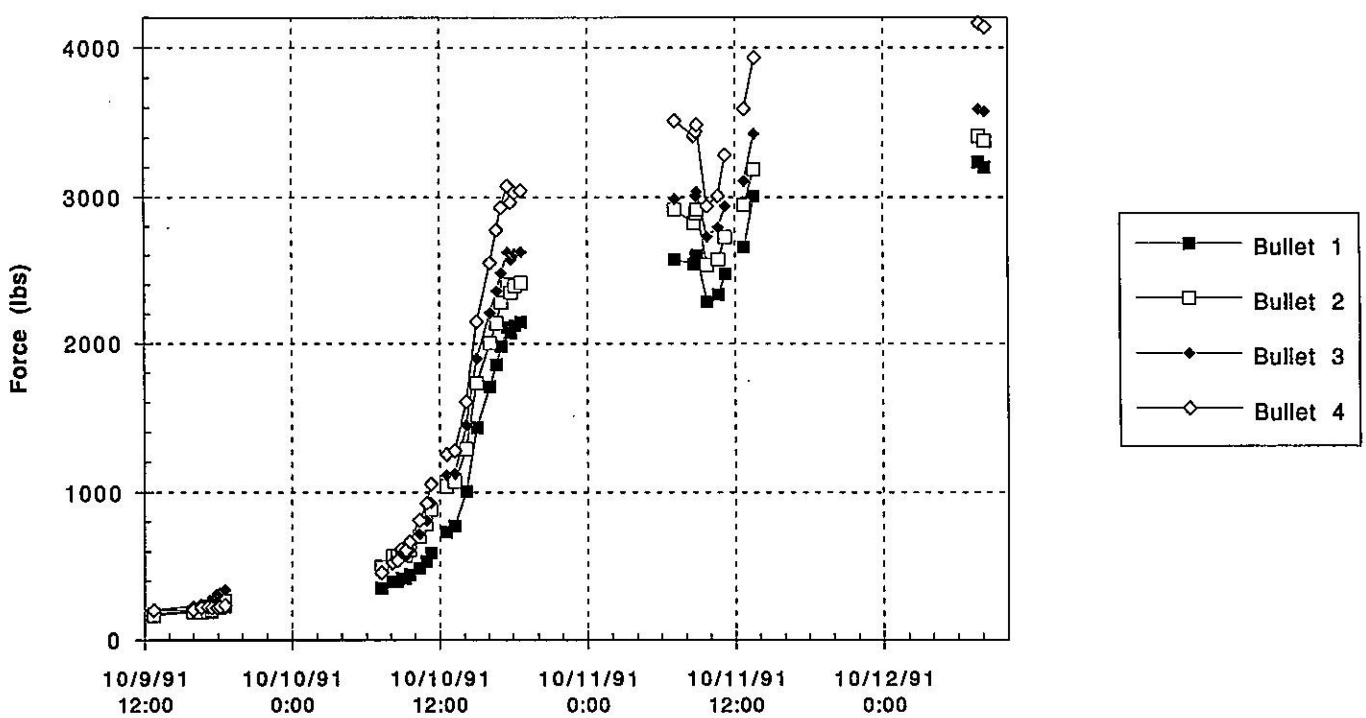


Figure 2

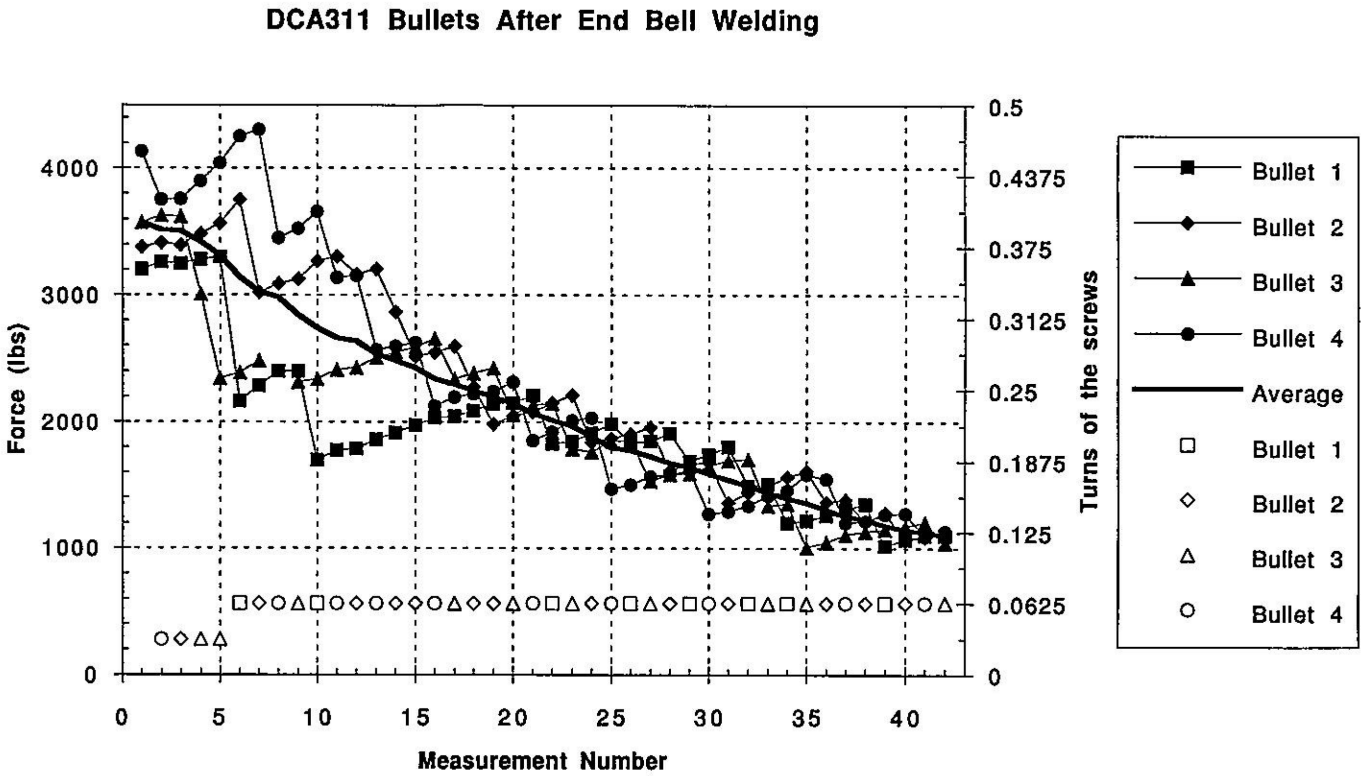


Figure 3

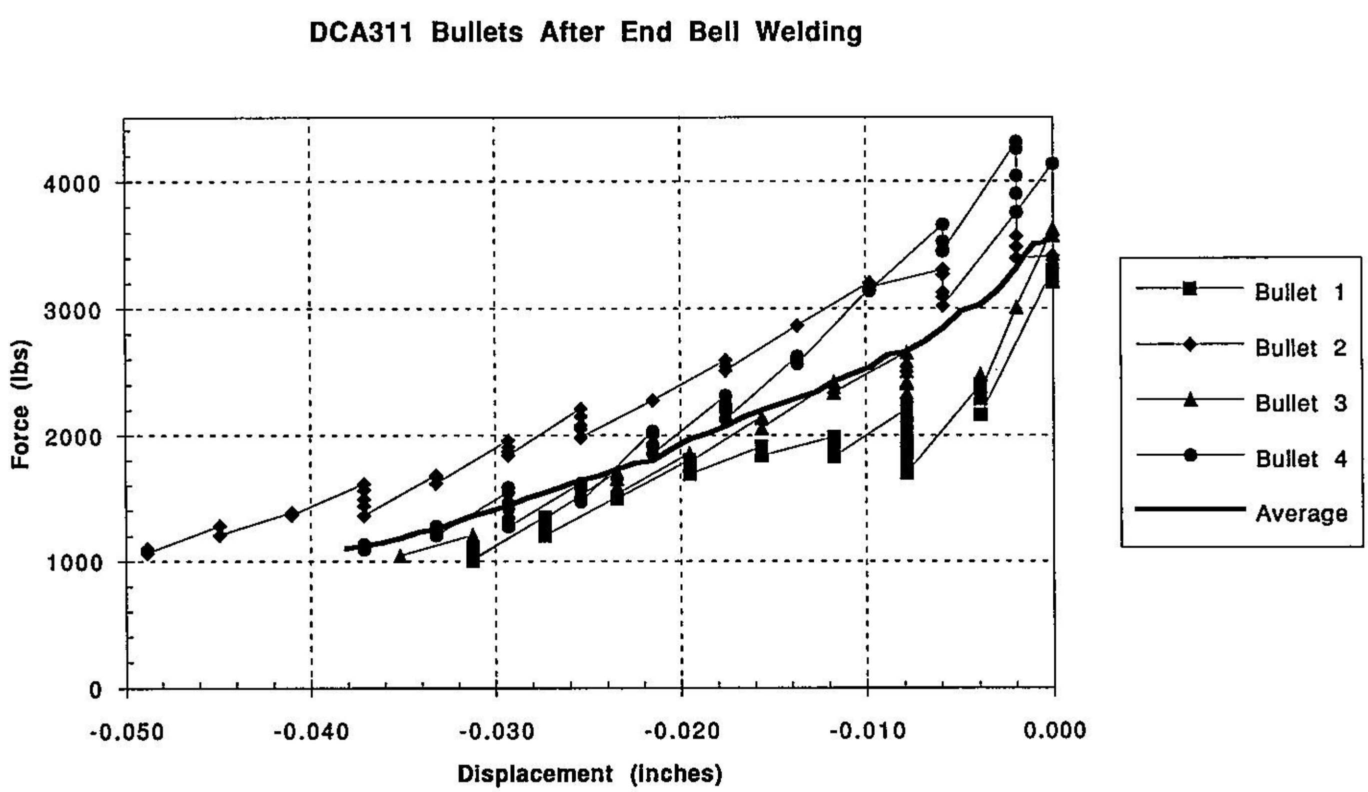
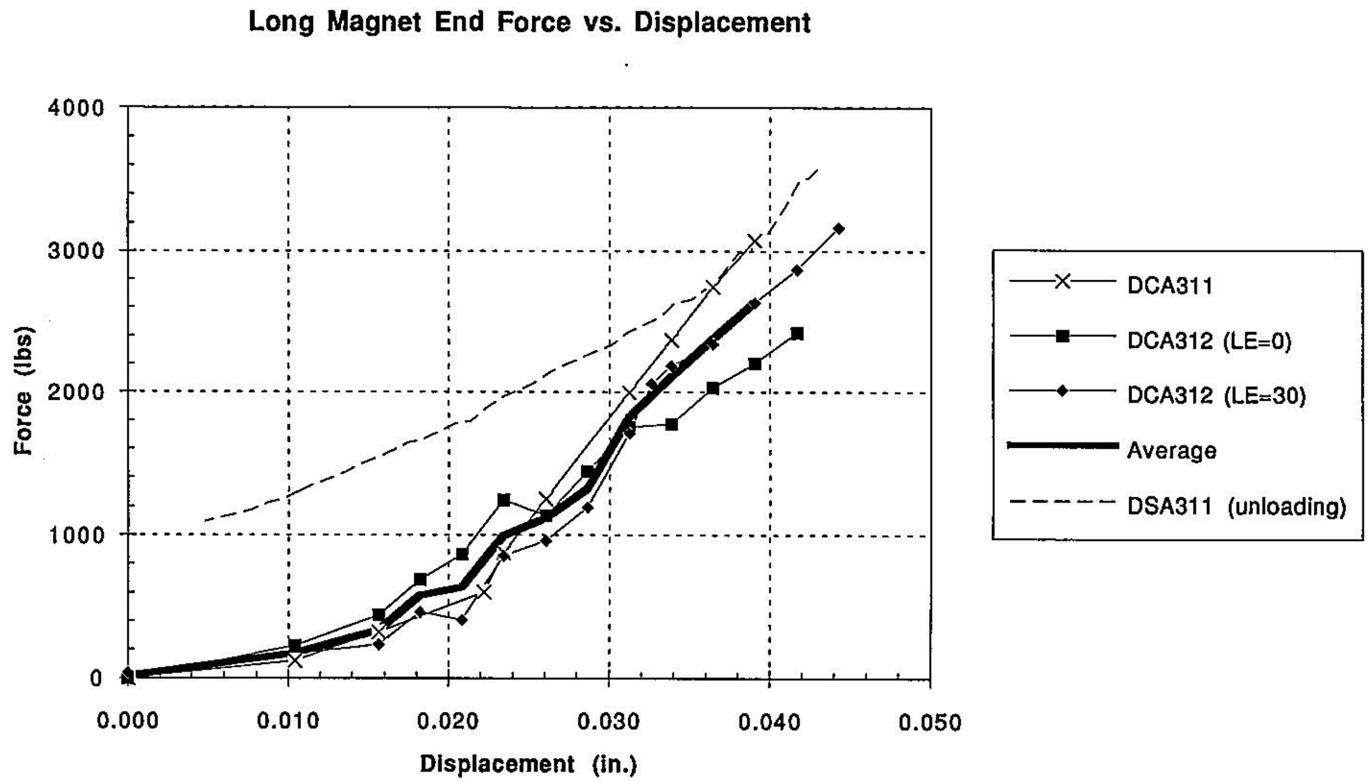


Figure 4



Long Magnet End Force vs. Displacement
4000
3000
2000
1000
0
Force (lbs)
0.000
0.010
0.020
0.030
0.040
0.050
Displacement (in.)
DCA311
DCA312 (LE=0)
DCA312 (LE=30)
Average
DSA311 (unloading)

Figure 5